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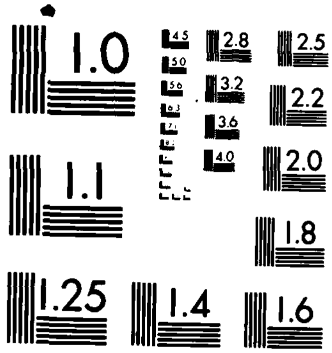
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OF

DEVELOPMENT OF IMPROVED BROADBAND CABLE SYSTEM COMMUNICATIONS

C. L. FRANCIS

DEVELOPMENT AND ANAYLSIS DIRECTORATE

U.S. ARMY COMBAT SYSTEMS TEST ACTIVITY
ABERDEEN PROVING GROUND, MD 21005-5059

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A broadband cable system was installed at U.S. Army Combat Systems Test Activity (USACSTA) in 1980 to allow data communication between test site data acquisition systems. The high-speed modems selected for this function were found to be unreliable and unmaintainable. This project was to investigate alternative equipment which would be suitable for providing high-speed data communications on the USACSTA broadband cable system. The investigation was

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20. conducted at USACSTA from May 1983 to August 1985. It is concluded that: (1) The Fairchild Data Corporation M505 provides the flexibility, reliability, and maintainability required for the USACSTA broadband network; (2) The best network topology consists of using a computer at Building 436 to perform network routing and not using a translator; (3) Routine preventive maintenance must be performed on the broadband cable system to maintain its effectiveness; (4) The CATEL DM-2100 provides adequate low-speed performance; (5) Additional cable drops must be provided to meet user needs; (6) An improved software data transfer utility must be created to support the broadband cable system requirements; (7) The addition of an audio-communications capability to the broadband cable system would increase its utility and improve range communications.

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FOREWORD

The U.S. Army Combat Systems Test Activity (USACSTA), Aberdeen Proving Ground (APG), MD, was responsible for study planning, investigation and reporting.

SECTION 1. BODY

1. BACKGROUND

An instrumentation modernization program called Automated Data Acquisition and Processing Technologies (ADAPT) was initiated 10 years ago. The philosophy of ADAPT was to develop minicomputer-based data acquisition systems which would be connected together in a network. There were to be two types of data acquisition systems (called test site terminals) having different front end hardware but sharing a similar computer system. One of these, the ballistic test site terminal (BTST), was to be networked using a broadband cable system while the other, the telemetry test site terminal (TTST), was to use a microwave communication network (app E, ref 1).

The first BTST was fielded in July 1980 with completion of the broadband cable network following shortly thereafter. During the next year the network was used intermittenly with the following results:

a. Reliability of the data modems was poor.

b. The BTST disc to BTST disc transfer rate of 1500 words per second made large data transfers time consuming.

c. Coordination of data transfers was slow and cumbersome.

d. Program file transfers were convenient.

Due to deterioration of data modem reliability, use of the broadband cable network dropped to zero by the end of 1982. A study of alternative modems was carried out by AAI Corporation (app E, ref 2). Subsequently a modem pair was purchased and evaluated. This report covers the development of an improved communication capability for the BTSTs.

2. BROADBAND CABLE SYSTEM

A broadband cable system provides a cost effective communication system when a concentration of users exists. The wide bandwidth of the cable allows a number of users to coexist simultaneously. The cost of cable installation is approximately $13,000 per mile and the cable equipment required in each trailer is less expensive than microwave equipment. A significant advantage of a broadband cable system is that no frequency allocation is required. It was primarily this factor which led to the choice of broadband cable for the BTST communication network. In addition, some measure of security is provided since only a very small amount of energy is radiated. The biggest disadvantage of a broadband cable system is that the cable must be run to and a connection interface must be installed at each location where communication is required. In the case of the BTSTs this is not a serious problem since the majority of firing sites are clustered together.

2.1 USACSTA Cable Plant

The ADAPT broadband cable system is composed of two essentially independent legs beginning at Building 436 (called the head end). One leg covers the main front ranges, Building 400 and Trench Warfare, while the other covers the water ranges. Each leg contains approximately 2.3 miles of cable. The cable used is 3/4-inch solid aluminum jacket to provide high shielding capability to prevent both ingress and egress.

The system supports two-way communication by dividing the available frequency spectrum. Frequencies from 170 to 300 MHz are used to communicate from Building 436 to the ranges (the forward direction), and frequencies from 5 to 115 MHz are used to communicate from the ranges back to Building 436 (the reverse direction).

To account for losses in the cable, amplifiers are spaced approximately every quarter mile. To account for temperature variation and aging, every third amplifier has automatic gain control (AGC). The AGC functions by monitoring pilot carriers: 181.25 MHz in the forward direction and 115.25 MHz in the reverse direction. Two reverse direction pilot carrier generators are required (one at the end of each cable leg).

The amplifiers are powered from 60 volts AC at 60 Hz carried on the cable itself. Each leg has its own independent AC supply. Each amplifier housing contains two trunk filters to separate the forward and reverse frequencies, two amplifiers (one for the forward direction and another for the reverse direction), plug-in slots for attenuators and equalizers, and a power supply.

Locations where cable signal input or output may be obtained are called drops. A drop consists of a directional coupler (typically 12 dB) attached to the cable system with RG-6 double shielded coaxial cable connecting the coupler to a type-F user accessible connector. The directional couplers are installed so that the drop can communicate with the head end. Thus, communication from one drop to another must be routed through the head end and translated in frequency in the process. There are currently 12 drops in the system at the locations listed in Table 1. Figure 1 gives a general view of the cable plant as it currently exists.

Table 1. CABLE DROP LOCATIONS

Main Front Leg	Water Ranges Leg
Trench Warfare	High velocity
Barricade 1	Barricade 680
Building 355	Railroad range
Barricade 4	New Barricade
Building 364 trailer pad	Ballistic range
Building 400	
Barricade 5	

2.2 Frequency Allocation

Since the equipment used to build the broadband cable system was originally intended for community antenna television (CATV) service, the allocation of frequencies has historically been in terms of television channels. These channels are typically 6 MHz wide and the cable frequency assignments for channels 2 to 13 are the same as the over-the-air channels. Letter designators are used for nonstandard channel assignments. The broadband cable system frequency assignments used by USACSTA are given in Table 2.

TABLE 2. CABLE FREQUENCY ASSIGNMENTS

Reverse Direction			Forward Direction		
Freq (MHz)	Channel	Use	Freq (MHz)	Channel	Use
5.75	T-7		168	I	Old modems
11.75	T-8	Old modems	174	7	Old modems
17.75	T-9	Old modems	180	8	Forward carrier generator
23.75	T-10	Low-speed modems	186	9	
29.75	T-11	CCTV Mod	192	10	Low-speed modems
35.75	T-12		198	11	CCTV Mod
41.75	T-13	CCTV Mod	204	12	
47.75			210	13	CCTV Mod
54	2	CCTV Mod	216	J	
60	3	CCTV Mod	222	K	Replacement Modem
66	4	CCTV Mod	228	L	
72			234	M	
76	5	CCTV Mod	240	N	
82	6	Replacement modem	246	O	
88	FM-1		252	P	
94	FM-2		258	Q	
100	FM-3		264	R	
106	FM-4		270	S	
112		Return carrier generator	276	T	
			282	V	
			294	W	

2.3 Head End Equipment

The head end consists of a trunk filter to separate the forward and reverse frequencies, a pilot carrier generator for forward direction AGC control, a translator for the modems, and numerous couplers and attenuators to glue everything together. Figure 2 is a connection diagram for the equipment originally installed at the head end.

2.4 BTST Equipment

The BTST cable equipment consists of a trunk filter to separate the forward and reverse frequencies, a modem, a closed circuit television (CCTV) modulator, a coupler, and an attenuator. The CCTV capability has been tested and works satisfactorily. However, the modems, as mentioned earlier, have shown poor reliability. Figure 3 is a connection diagram for the equipment originally mounted in the BTSTs.

2.5 Modem Problems

Six pairs of modems were purchased to provide communication between the BTSTs and the Process Controller located at Building 436. The problems encountered with the modems were:

a. Failure to lock to the carrier when first powered on. This could often be resolved by removing the input cable and then reinstalling it to shock the modem into lock. This problem normally got worse with time and eventually reached the point where lock could not be achieved under any circumstances.

b. High error rates making communication between computers slow due to retransmission, or impossible due to too many errors.

c. Failure to transmit data at all, even though carrier lock was obtained.

d. Restricted temperature range. Low and/or high temperatures often produced the problems described above.

Although significant effort was expended by the cable installer, the modem manufacturer, and USACSTA personnel, the modems could not be kept functioning for any extended period of time. The modems displaying the greatest problems were those mounted in the BTSTs where power interruptions and large temperature variations were experienced. It was eventually concluded that the modem design was not adequate for the field environment encountered in a BTST and efforts to keep the modems operational were abandoned.

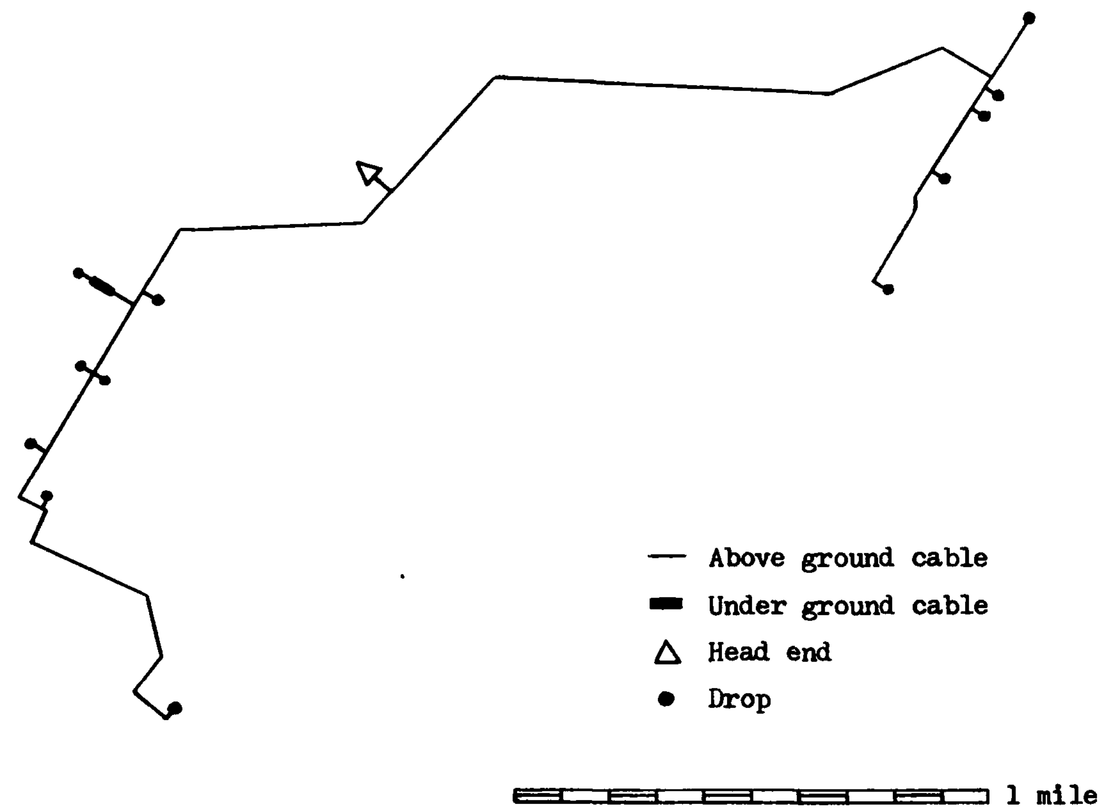

Figure 1. Current cable configuration.

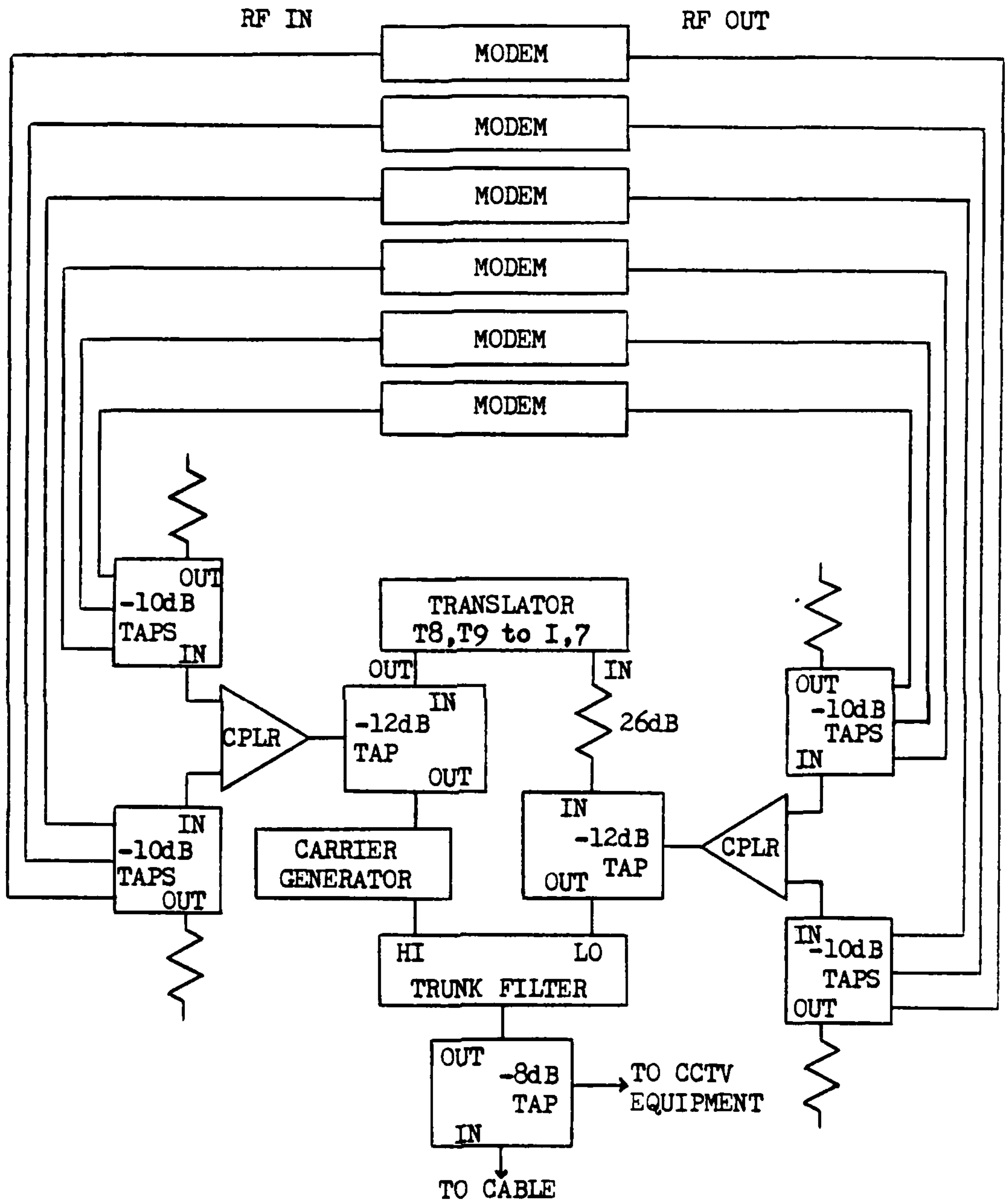

Figure 2. Original head end cable equipment configuration.

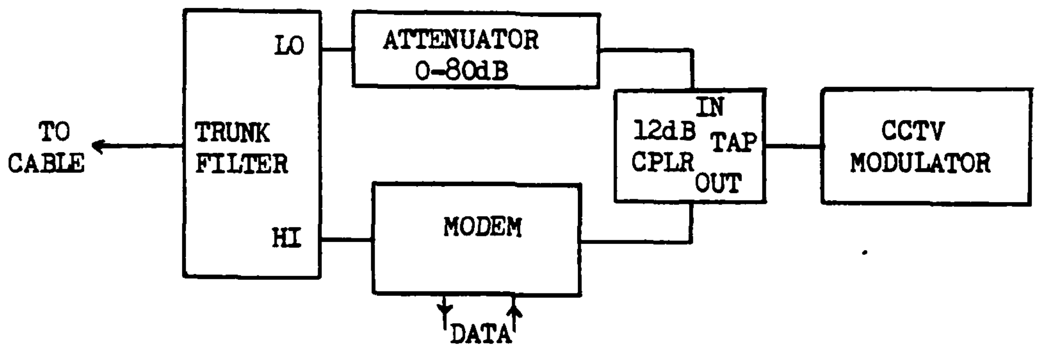

Figure 3. Original BTST cable equipment configuration.

3. REPLACEMENT MODEMS

In 1983, as part of a study of the ADAPT communication network, AAI Corporation performed a market study (app E, ref 3) to determine if a better modem was available. Several candidates were located; however, the COMTECH M500 appeared to be the best candidate as it required no major changes in existing hardware or software.

3.1 COMTECH M500 Modem

The COMTECH M500 is similar in design to the original modems used in the ADAPT network. However, it uses fewer parts, has fewer adjustments, and uses newer, more stable technology than the older modems. The specifications for the M500 are in Table 3.

TABLE 3. COMTECH MODEL M500 MODEM SPECIFICATIONS

Item	Measurement
Data rate	56 kbps to 7 Mbps (fixed)
Carrier frequency	5 to 440 MHz
Output level	+30 dBmV to +45 dBmV (adjustable)
Spacing	0.7 times data rate
Clock	External (synchronous)
Input level	-12 dBmV to +5 dBmV
Bit error rate	1×10^{-9} with 30 dB carrier to noise ratio
Interface	RS-449, V .35 or T1
Operating temperature	0 °C to +40 °C

3.2 Initial Evaluation

A pair of M500 modems were borrowed from the manufacturer to test their reliability. The pair borrowed were delivered to operate at frequencies of 85 MHz and 225 MHz with input and output frequencies inverted to eliminate the need for a translator. The data rate for these modems was 230.4 k bits per second (bps) to match the DS-1000-IV modem cards in a pair of Hewlett-Packard A-600 computers.

The modems were initially tested using the configuration shown in Figure 4. Both modems were placed in a BTST so that they would receive the harsh environment of the field. The modems were tested over a 1-month period in the BTST and a 1-day test was made with one modem at Building 436 and the other in a BTST. The modems appeared to perform properly except that one required a warm-up period before it would go into lock. The length of warm-up was dependent on temperature. This problem was encountered with the original modems used and usually worsened with time. The COMTEC modem did not demonstrate any deterioration with time.

The memory-to-memory data transfer rate was measured using programs M1000 and S1000. These programs were derived from similar programs used in the early ADAPT communication network. Listings are in Appendix A.

Since the only evaluation tool available was these programs, a quantitative assessment of the modems' bit error rates was not possible. However, other than the warm-up problem, there were no indications that the modems would not perform properly.

One item of interest noted during the evaluation was that the DS 1000-IV modem card operating at 230.4 kbps could outperform a 12771 serial interface card operating at 1 Mbps.

3.3 Second Evaluation

Based on the initial evaluation, it was determined that a pair of modems would be purchased for a longer, more detailed evaluation. Frequencies of 85 MHz and 225 MHz were used again, but a data transfer rate of 1 Mbps was selected to allow testing with the Hewlett-Packard 12771 serial interface card.

The 12771 serial interface card is a direct connect, asynchronous design with a maximum data rate of 1 Mbps. To make the 12771 card work with the COMTECH synchronous, RS-449 modems required that the following changes be made:

a. An RS-449 driver integrated circuit was added to generate the required data and clock output signal levels.

b. The current limiting resistor in the optically isolated input stage was changed to match the modem's RS-449 output.

c. A monostable multivibrator was installed and several wiring changes were made to synchronize the output data with the clock.

d. The card crystal oscillator circuit was modified to reduce loading so the frequency would be correct.

Details of the modification are in Appendix B. Items a, b, and d are reversible if carefully implemented. Item c, however, involves destructive changes to the board. A pair of cards were modified for the evaluation.

In order to verify the modifications, it was necessary to write a special driver and a control program to set the output of the 12771. These programs allowed the data and clock to be compared with a known data word and repetition rate. These facilities were not provided in DS-1000. Listings of these programs are in Appendix C.

The card modifications were initially tested by placing two BTSTs within 100 feet of each other and connecting them as in Figure 4. The system was found to work quite reliably as long as one of the modems was not in the temperature range of 60 to 70 °F. In this range the modem would not lock to the carrier of the other modem. When there is no carrier detect, the modem puts out noise which ties up the computer in responding to spurious interrupts. To eliminate the interrupt problem, the carrier detect signal was wired to the RS-449 driver enable input on each modem's interface board. This course was selected because a major change to the 12771 card would have been required to accomplish the same result.

Since the use of the computer to test the modems did not provide quantitative results and tied up two computers, it was decided to build a tester which would overcome these problems. The details of the tester are in Appendix D. The tester generates a synchronous data signal which is output to a modem and to a digital delay circuit. The input signal from a modem is compared to the delayed signal and any differences are counted as errors. The tester requires that the delay be set correctly initially.

With both modems located in the same BTST and connected in the configuration of Figure 4, the tester found no errors as long as the temperature was not in the 60 to 70 °F range. A delay of 93 microseconds was required on the tester.

One of the modems was then moved to Building 436 and set up in the configuration of Figure 5 with the BTST modem set up as indicated in Figure 3. The tester error rate was variable from nearly perfect to very bad. Sandwiching the modem at Building 436 between two other pieces of equipment to keep it warm improved the situation somewhat (the computer room in Building 436 is cooler than the BTST). A delay of 104 μs was required on the tester.

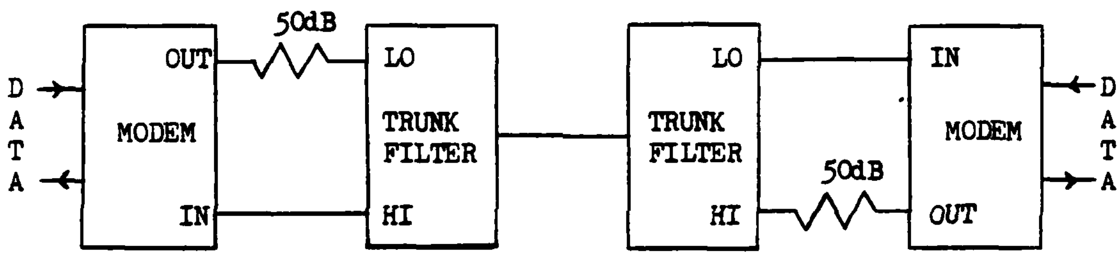

Figure 4. Configuration for initial tests of improved high-speed modems.

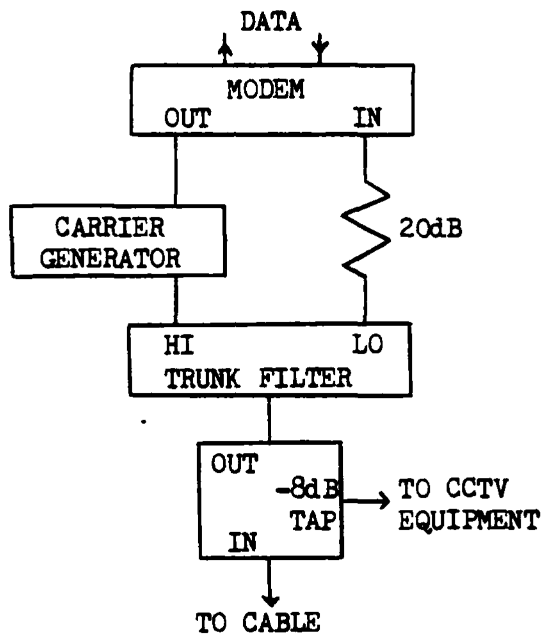

Figure 5. Head end configuration for test of improved high-speed modems.

At this point the modems were returned to the manufacturer for repair. When returned, the modems were checked in the BTST again. This time there were no problems encountered. However, when one of the modems was installed at Building 436, a higher than expected error rate was found. Since the modems worked perfectly connected directly, the assumption was made that the problem was with the broadband cable system. Although the signal levels and spectra were monitored, nothing abnormal was observed. A cable evaluation contract with the company which installed the cable system was initiated. The evaluation discovered:

a. A break in the cable disconnecting the return carrier generator for one leg from the majority of the system (the leg in use for the tests).

b. Several kinks in the cable giving undesirable responses.

c. A bad connection at a drop.

d. Two amplifier housings with leaks.

With the exception of the last item, repairs were carried out to correct all deficiencies.

Once the cable was repaired, it was found that the modems worked perfectly on the cable system. After 40 days of flawless operation, the modem at Building 436 failed to lock after a power outage. The problem was traced to the input local oscillator failing to start. A simple internal adjustment was made and the unit returned to operation.

Following the cable repairs, testing consisted of a mixture of bit-error-rate testing using a commercial tester and DS-1000 communication. A compilation of various data transfer rates measured using DS-1000 is in Table 4. The data transfer rate from a BTST to another BTST could not be measured since only one pair of modems was available. Node 200 is networked to node 100 with 12771 serial interface cards connected by twisted pair wire. The memory- to-memory transfer rates were measured using M1000 and S1000 listed in Appendix A. The disk-to-disk transfer rates were measured using MDISC and SDISC described in Appendix E, Reference 2.

TABLE 4. MEASURED DS-1000 DATA TRANSFER RATES WITH COMTECH M500 MODEMS

TYPE OF TRANSFER	WORDS PER SECOND
BTST to node 100 memory-to-memory	4100
BTST to node 200 memory-to-memory	2580
BTST to node 100 disk-to-disk	3280
BTST to node 200 disk-to-disk	2100

3.4 Modem Availability

COMTECH has been purchased by Fairchild Data Corporation. The M500 modem has been discontinued by the manufacturer and replaced by the M505 modem. A manual for the M505 was obtained from the manufacturer (app E, ref 4). The M505 design is essentially the same as the M500 with the following differences:

a. A synthesizer has been used instead of crystals for setting the modem's transmitter and receiver frequencies. The synthesizer frequencies are programmed using a wired connector. This has the advantage that all modems become interchangeable by merely changing the synthesizer frequency programming. The disadvantage is increased complexity and potentially noisier output.

b. The modem data rate can be changed by the user if a data rate kit is purchased for each modem. The M500's data rate can be changed only at the factory.

c. The modulator, demodulator, and interface adapter unit are now easily removable printed circuit cards instead of being modem assemblies. This is a definite advantage for troubleshooting.

d. The transmitter synthesizer, transmitter module, receiver synthesizer, receiver module, modulator, demodulator, interface adapter unit, and power supply can all be returned separately for repair. With the M500, the entire modem had to be returned.

e. All controls and test points are accessible behind a drop front panel. On the M500, controls were on the front panel and test points required removing the top cover.

Overall, the design of the M505 should make maintenance considerably easier than on the M500.

3.5 Network Topology

The original modems made use of a translator. Translators convert a reverse frequency into a forward frequency through upconversion. Normally a translator covers an entire 6 MHz TV channel, but double channel translators are sometimes used. Translators add complication and increase the noise level on a channel. Translators are required if communication between different nonhead end locations is desired. However, translators cannot provide a switching capability between different locations as a function of time.

The original BTST network was configured as a star (a central node with all remote nodes connected to it). The process control computer served as the switching element to allow any computer to talk to any other computer in the network. This arrangement allows the simplest cable configuration but places a heavy burden on the central computer. With the improved DS-1000/IV hardware and software and the addition of the slave computer, this burden is not intolerable.

There are basically three possible network configurations which could be implemented:

a. Use the current slave computer at the head end with no translator on the cable system. This is the simplest implementation, but it places half of all modems and the switching computer out of operational control of the owning organization.

b. Move the current slave computer (or purchase a new computer) to Building 363 (or other suitable location) and use a translator at the head end. This is a more complicated approach but places ownership and operational control together (except for the translator).

c. Move the head end from Building 436 to Building 363 (or other suitable location) along with the slave computer (or purchase a new computer) and use no translator. This is the most complicated implementation but places all ownership and operational control together.

4. LOW SPEED MODEMS

An auxiliary investigation was initiated to determine the reliability and ease of use of low-speed modems (up to 9600 kps). The modems chosen for the investigation were the CATEL model DM-2100 asynchronous modems. Characteristics of the modems are in Table 5. Since communication between different nonhead end locations was anticipated, a TOMCO Communication Company model C-285 translator was also purchased. Characteristics of the translator are in Table 6.

TABLE 5. LOW-SPEED MODEM CHARACTERISTICS

Item	Measurement
Data rate	0 to 9600 bps
Carrier frequency	4 to 200 MHz
Output level	+30 to +45 dBmV
Spacing	300 kHz
Clock	Asynchronous
Input level	-10 to 0 dBmV
Bit error rate	1×10^{-8} with 25 dB carrier to noise ratio
Interface	RS-232C
Operating temperature	+10 to +40 °C

TABLE 6. TRANSLATOR CHARACTERISTICS

Item	Measurement
Input frequency range	5 to 88 MHz
Output frequency range	52 to 300 MHz
Bandwidth	5 MHz at -3 dB; 7 MHz at -40 dB
Input level	0 to +10 dBmV
Noise figure	10 dB maximum
Frequency stability	750 Hz
Spurious outputs	-5 dBmV maximum
Operating temperature	0 to +40 °C

The modems and translator were initially set up in a BTST as shown in Figure 6. Tests in this configuration revealed no modem reliability or data error problems over a wide temperature range. The translator exhibited an oscillator start-up problem which was not detrimental to the tests.

The modems were tested on the cable system using the setup of Figure 7. Again, good reliability and low data error rates were obtained. No interaction between the high-speed and low-speed modems was observed.

After several weeks of operation, the system started to show errors and tester synchronization losses. The problem was traced to the translator second local oscillator. The translator was returned to the manufacturer for repair. When returned, the system again operated with low data error rates and no tester synchronization losses.

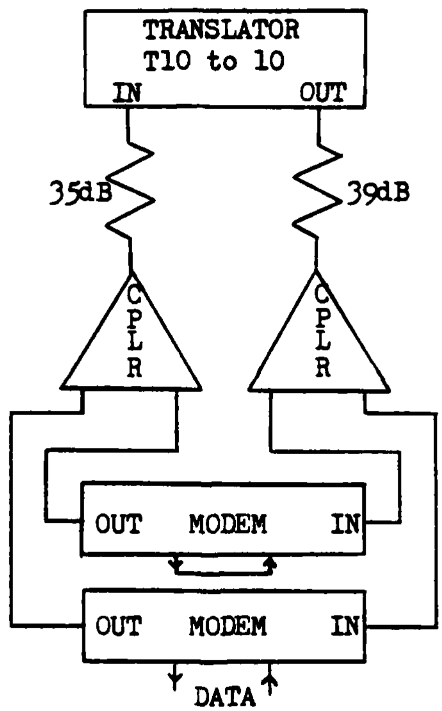

Figure 6. Configuration for initial tests of low-speed modems.

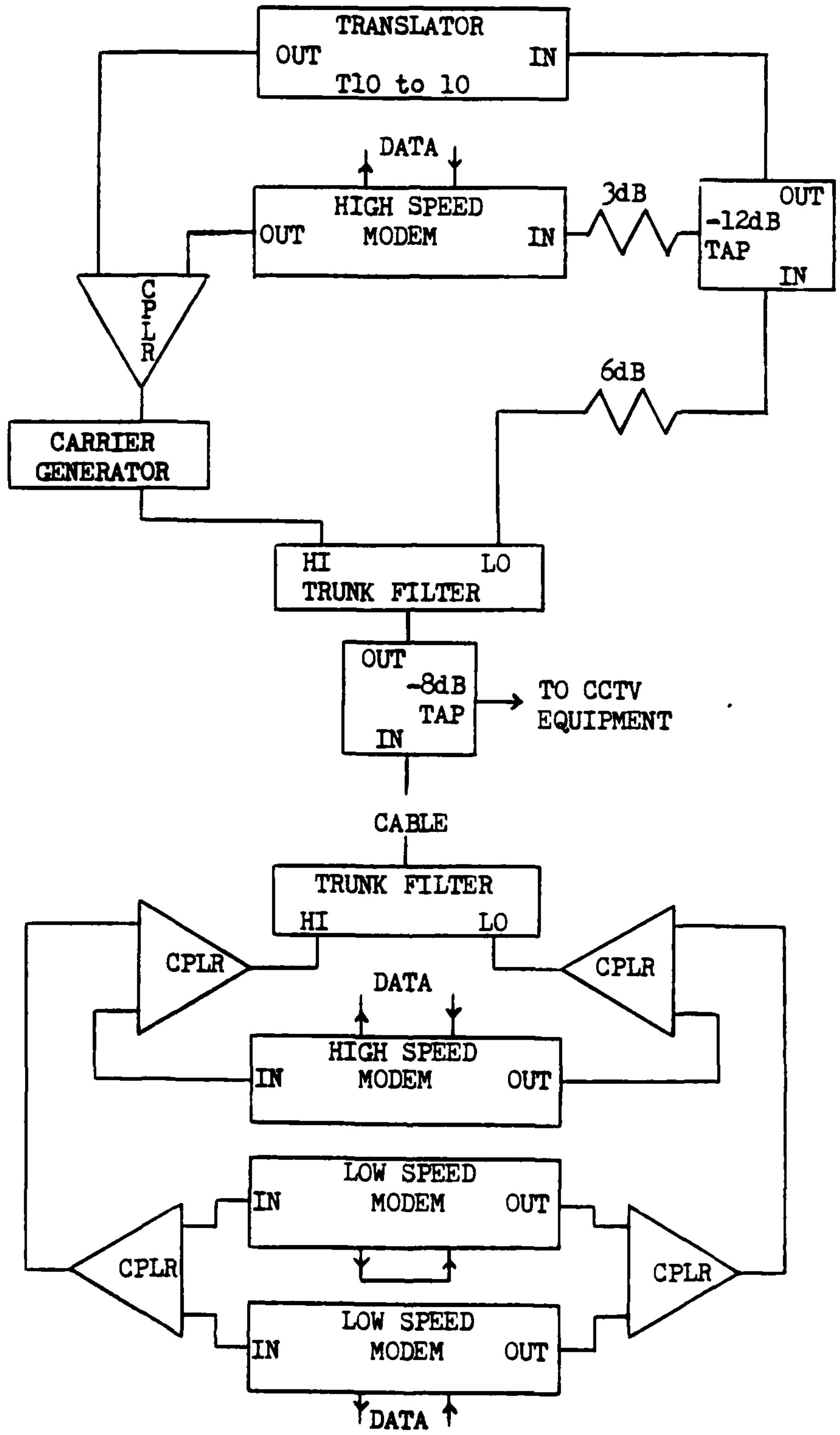

Figure 7. Configuration of BTST and head end for test of low-speed modems.

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5. ADDITIONAL CABLE DROPS

The addition of drops close to the existing system is not particulary expensive or difficult. However, each drop adds the potential for interference entering the system and increases the maintenance burden. Drops must be properly terminated when not used. Extensions to the system are considerably more expensive and difficult to implement.

Interest has been expressed in adding drops to the cable system at the following locations:

a. Building 350, Instrumentation Development Division; to connect existing computers.

b. Building 374, Ballistics Measurement Division; for BTST 374.

c. Pad near Building 364, Ballistics Measurement Division; to improve existing drop.

6. SOFTWARE SUPPORT

Currently, programs MDISC and SDISC allow data residing on a disc in one location to be transfered to a disc in another location. While this basically satisfies the need to move data quickly from a trailer to an analysis facility, the existing programs have the following deficiencies:

a. There is no mechanism to prevent a remote unit from overwriting valuable data at the central (or any other) computer.

b. There is no mechanism to prevent two remote units from writing to the same disc location simultaneously.

c. The potential exists for data from different tests to be mixed together.

d. The ability to read data from any remote unit exists.

7. COMMUNICATIONS

The modems described in paragraphs 3 and 4 provide a means of transferring data from a BTST to a central computer. In addition to this requirement, an audio communication capability would be useful. Currently, BTSTs have a frequency modulation (FM) radio installed and a standard telephone. The radio provides half-duplex communication on a channel shared by many users. The telephone must be connected into an existing jack and is usually shared with others.

The broadband cable system provides a way to conduct full-duplex communications on a large number of channels. With the installation of an appropriate switching network at the head end and transceivers in each BTST, an improvement in range communications could be achieved. Unfortunately, a market search has revealed no source of commercially manufactured equipment.

8. CONCLUSIONS

It is concluded that:

a. The Fairchild Data System M505 provides the flexibility, reliability, and maintainability required for the USACSTA broadband network.

b. The best network topology consists of using a computer at Building 436 to perform network routing and not using a translator.

c. Routine preventive maintenance must be performed on the broadband cable system to maintain its effectiveness.

d. The CATEL DM-2100 provides adequate low-speed performance.

e. Additional cable drops must be provided to meet user needs.

f. An improved software data transfer utility must be created to support the broadband cable system requirements.

g. The addition of an audio communications capability to broadband cable system would increase its utility and improve range communications.

9. RECOMMENDATIONS

It is recommended that:

a. The Fairchild Data Systems M505 be purchased for high-speed data transfer applications.

b. A computer at Building 436 be used to perform network routing with no translator used in the system.

c. A broadband cable system maintenance contract be initiated.

d. Additional cable drops be added where needed.

e. An improved software data transfer utility be developed or acquired.

f. The development of an audio communications capability be investigated.

SECTION 3. APPENDICES

APPENDIX A - PROGRAMS M1000 AND S1000 LISTINGS

```
FTN4
      PROGRAM M1000(3,50),  REV B  18APR84  CLF
C
C************************************************************************
C
C   THIS PROGRAM ACTS AS THE MASTER OFR DS/1000 PROGRAM TO PROGRAM
C   DATA TRANSFERS TO MEASURE THE EFFECTIVE TRANSFER RATE.
C
C    RU,M1000,INTRCTV LU(DFLT=1),LIST LU(DFLT=INTRCTV LU),NTIMES(DFLT=1)
C
C     TAG WORDS PASSED ARE:
C       ITAG(1)=BUFFER SIZE
C       ITAG(5)=CLASS #
C       ITAG(10)=MODE
C
C   REV B   03MAR83  CLF  MODIFY FOR DS-1000/IV.
C           22MAY83  CLF  ADD MODE & ICOUNT.
C           18MAY84  CLF  ADD REPETITIVE OPERATION & LIST LU.
C   REV A   15MAY79  PLP  ORIGINAL.
C
C************************************************************************
      DIMENSION IPCB(4),ITAG(20),IP(5),IBUF(4096),ISTART(5),ISTOP(5)
      DOUBLE PRECISION TIME,RATE,WORDS
      DATA MODE1/1/,MODE2/2/
      CALL RMPAR(IP)
      LU=IP(1)
      IF(LU .EQ. 0)LU=1
      LIST=IP(2)
      IF(LIST .EQ. 0)LIST=LU
      NTIMES=IP(3)
      IF(NTIMES .LE. 0)NTIMES=1
      WRITE(LU,100)
  100 FORMAT(">M1000:  ENTER REMOTE NODE NO:_")
      READ(LU,*)NODE
      WRITE(LU,120)
  120 FORMAT(">M1000:  ENTER NO OF WORDS PER BLOCK(1-4096):_")
      READ(LU,*)IBFSZ
      IF(IBFSZ .LT. 1 .OR. IBFSZ .GT. 4096)IBFSZ=4096
      WRITE(LU,140)
  140 FORMAT(">M1000:  ENTER NUMBER OF BLOCKS TO BE PASSED:_")
      READ(LU,*)KOUNT
      IF(KOUNT .LE. 0)KOUNT=1
      WRITE(LU,145)
  145 FORMAT(">M1000:  ENTER MODE (0=0, 1=1, 2=SEQ, 3=RNDM):_")
      READ(LU,*)MODE
      IF(MODE .LT. 0 .OR. MODE .GT. 3)MODE=2
C ***** PRINT HEADER IF LIST LU WAS SUPPLIED
      IF(LIST .NE. LU)WRITE(LIST,150)NODE,IBFSZ,KOUNT,MODE
  150 FORMAT(3X,"NODE = ",I4,"  BUFR SIZE = ",I4,"  NO OF BLKS = ",I5,
     $  "  MODE = ",I1//)
C ***** LOOP NTIMES
  155 DO 410 NN=1,NTIMES
C******FILL BUFFER WITH DUMMY DATA
      DO 160 I=1,IBFSZ
  160 IBUF(I)=-12345
C ***** SET MODE
      ITAG(10)=MODE
C ***** SCHEDULE SLAVE
      CALL POPEN(IPCB,IERR,6HS1000 ,NODE,ITAG)
C ***** CHECK IF SLAVE STARTED
      IF(IERR .EQ. 0)GO TO 200
      WRITE(LU,180)IERR
  180 FORMAT(">M1000:  CALL POPEN ERROR.  IERR = ",I3)
      STOP 1
```

```
  200 WRITE(LU,220)
  220 FORMAT(">M1000:  SLAVE IS SCHEDULED")
C ***** READ START TIME
      CALL EXEC(11,ISTART)
C ***** LOOP TO READ SPECIFIED NO OF BLOCKS
      DO 260 K=1,KOUNT
      ITAG(1)=IBFSZ
C ***** READ DATA
      CALL PREAD(IPCB,IERR,IBUF,IBFSZ,ITAG)
      IF(IERR .GE. 0)GO TO 260
      WRITE(LU,240)IERR,I
  240 FORMAT(">M1000:  CALL PREAD ERROR.  IERR = ",I3,"  BLK = ",I5)
      CALL PCLOS(IPCB,IERR)
      STOP 2
  260 CONTINUE
C ***** READ STOP TIME
      CALL EXEC(11,ISTOP)
C ***** DETERMINE TIMING INFORMATION
      ISTART(1)=ISTART(1)*10
      ISTOP(1)=ISTOP(1)*10
C     WRITE(LU,300)(ISTART(I),I=4,1,-1),(ISTOP(I),I=4,1,-1),ITAG(5)
C 300 FORMAT(3X"INITAL TIME:  "I2":"I2":"I2"."I3,/
C    &       3X"   STOP TIME:  "I2":"I2":"I2"."I3/
C    &       3X"CLASS # = "I5)
      IF(ISTOP(1) .GE. ISTART(1))GO TO 320
      ISTOP(1)=ISTOP(1)+1000
      ISTOP(2)=ISTOP(2)-1
  320 IF(ISTOP(2) .GE. ISTART(2))GO TO 340
      ISTOP(2)=ISTOP(2)+60
      ISTOP(3)=ISTOP(3)-1
  340 IF(ISTOP(3) .GE. ISTART(3))GO TO 360
      ISTOP(3)=ISTOP(3)+60
      ISTOP(4)=ISTOP(4)-1
  360 IF(ISTOP(4) .GE. ISTART(4))GO TO 370
      ISTOP(4)=ISTOP(4)+24
  370 XMSEC=ISTOP(1)-ISTART(1)
      XTSEC=ISTOP(2)-ISTART(2)
      XTMIN=ISTOP(3)-ISTART(3)
      XTHR=ISTOP(4)-ISTART(4)
      WORDS=DBLE(FLOAT(KOUNT))*DBLE(FLOAT(IBFSZ))
      TIME=DBLE(XMSEC)/1000.D0+DBLE(XTSEC)+DBLE(XTMIN)*60.D0+
     &  DBLE(XTHR)*3600.D0
      RATE=WORDS/TIME
      CALL DBLPR(MODE1,LU,LIST,LUWRIT,IOPTN)
  375 WRITE(LUWRIT,380)NN,WORDS,TIME,RATE
  380 FORMAT(/3X,"N = ",I5,2X,I9," WORDS IN ",F7.2,
     $  " SEC = RATE OF ",I5," WPS")
      WRITE(LUWRIT,400)IBUF(1),IBUF(IBFSZ)
  400 FORMAT(3X,"DATA CHECK: FIRST WORD= ",I6," LAST WORD= ",I6)
      CALL DBLPR(MODE2,LU,LIST,LUWRIT,IOPTN)
      IF(IOPTN .EQ. 1)GO TO 375
      CALL PCONT(IPCB,IERR,ITAG)
      CALL PCLOS(IPCB,IERR)
  410 CONTINUE
C ***** CHECK IF ADDITIONAL REQUESTS ARE DESIRED
  420 WRITE(LU,440)
  440 FORMAT(">M1000:  REPEAT SAME TEST (Y OR N)?_")
      READ(LU,460)IANS
  460 FORMAT(A1)
      IF(IANS .NE. 1HY .AND. IANS .NE. 1HN)GO TO 420
      IF(IANS .EQ. 1HY)GO TO 155
      END
      END$
```

```
FTN4
      PROGRAM S1000(),  REV B  20JUN83  CLF
C
C*********************************************************************
C
C   SLAVE PROGRAM FOR TESTING PROGRAM TO PROGRAM COMMUNICATION ON THE
C   DS/1000 NETWORK.
C
C   REV B   02MAR83  CLF   RENUMBER LINES IN SEQUENCE.
C           22MAY83  CLF   ADD MODE CAPABILITY.
C           20JUN83  CLF   ADD RANDOM NUMBERS TO DATA STATEMENT.
C   REV A   15MAY79  PLP   ORIGINAL.
C
C*********************************************************************
C
      DIMENSION ITAG(20),IP(5),IDCB(144),IBUF(4096),ITIME(5)
      DIMENSION IRNDM(50)
      DATA IRNDM/-12117,14466,-10005,24489,-30129,-20684,9752,-22895,
     $ -25416,-7836,-16441,-30946,-30664,-24995,-32355,6059,25786,
     $ -29577,-12127,11860,-13935,13147,-15933,32095,-6199,4380,-5905,
     $ 13351,-29851,-15906,-26583,24475,32033,-22037,-5004,-20902,
     $ 20047,25818,-21591,-20707,3975,22793,-527,-2362,-7799,-7067,
     $ -18695,-11441,-11087,12813/
      CALL RMPAR(IP)
C ***** GET CLASS NUMBER FOR COMMUNICATION WITH MASTER
      ICLAS=IP(1)
      IBFSZ=0
  100 CALL GET(ICLAS,IERR,IFUN,ITAG,IL)
      IF(IERR .EQ. 0)GO TO 160
      WRITE(1,120)IERR
  120 FORMAT("/S1000: CALL GET   ERROR.  IERR = "I3/)
      CALL REJCT(ITAG,IERR)
      IF (IERR .EQ. 0)GO TO 100
      WRITE(1,140)IERR
  140 FORMAT("/S1000:  CALL REJCT ERROR.  IERR = ",I3)
      CALL FINIS
      STOP 10
C ***** BRANCH TO APPROPRIATE PROCESSING SECTION
  160 IF(IFUN .EQ. 1)GO TO 200
      IF(IFUN .EQ. 2)GO TO 300
      IF(IFUN .EQ. 4)GO TO 600
C ***** IF REACH HERE, ILLEGAL REQUEST
      WRITE(1,180)IFUN
  180 FORMAT("/S1000:  ILLEGAL FUNCTION CODE.  IFUN = ",I3)
      CALL REJCT(ITAG,IERR)
      CALL FINIS
      STOP 11
C ***** ACCEPT POPEN SCHEDULING CALL
  200 CALL ACEPT(ITAG,IERR)
      IF(IERR .EQ. 0)GO TO 100
      WRITE(1,220)IERR
  220 FORMAT("/S1000:  CALL ACEPT ERROR.  IERR = ",I3)
      CALL FINIS
      STOP 12
C ***** PREPARE FOR BUFFER TRANSFER
  300 ITAG(5)=ICLAS
      IBFSZ=ITAG(1)
      IF(IBFSZ .GE. 1 .AND. IBFSZ .LE. 4096)GO TO 340
      WRITE(1,320)IBFSZ
  320 FORMAT("/S1000:  ERROR IN BUFFER SIZE.  IBFSZ = ",I6)
      CALL FINIS
      STOP 13
  340 MODE=ITAG(10)
      IF(MODE .GE. 0 .AND. MODE .LE. 3)GO TO 380
      WRITE(1,360)MODE
  360 FORMAT("/S1000:  ERROR IN MODE.  MODE = ",I5)
      CALL FINIS
      STOP 14
  380 CONTINUE
  400 IF(MODE .EQ. 0 .OR. MODE .EQ. 1)GO TO 440
      IF(MODE .EQ. 3)GO TO 480
```

```
C ***** MODE 2 - FILL BUFFER WITH SEQUENTIAL NUMBERS
      ICOUNT=ITAG(15)
      DO 420 I=1,IBFSZ
      ICOUNT=ICOUNT+1
  420 IBUF(I)=ICOUNT
      GO TO 520
C ***** MODE 0 & 1 - ALL ZEROES OR ALL ONES
  440 DO 460 I=1,IBFSZ
  460 IBUF(I)=MODE
      GO TO 520
C ***** MODE 3 - RANDOM NUMBERS
  480 DO 500 I=1,IBFSZ
      J=J+1
      IF(J .GE. 51)J=1
      IBUF(I)=IRNDM(J)
  500 CONTINUE
C******ACCEPT READ CALL AND PASS DATA IN IBUF
  520 CALL ACEPT(ITAG,IERR,IBUF)
      IF(IERR .EQ. 0)GO TO 100
      WRITE(1,540)IERR
  540 FORMAT(">S1000:  ERROR IN BUFFER TRANSFER.  IERR = ",I3)
      CALL FINIS
      STOP 15
C ***** NORMAL TERMINATION
  600 CALL ACEPT(ITAG,IERR)
      CALL FINIS
      END
      END$
```

APPENDIX B - DETAILS OF SERIAL INTERFACE MODIFICATION

As supplied by Hewlett-Packard, the 12771 serial interface card is designed for asynchronous, direct connect usage. For this application, compatibility with synchronous, RS-449 equipment was required. The changes required to make this conversion are described below.

The first change was to add an RS-449 driver integrated circuit (IC) to the board to produce the correct levels for the external equipment. The IC was mounted upside down, with double sticky tape, to an open area near the edge connector on the 12771 card. The data output was taken from pin 6 of U64 (see Fig. B-1). The signal at this point is transistor-transistor-logic (TTL) as required by the driver IC. The clock output was taken from pin 9 of U63. This is a 1 MHz TTL square wave signal. The outputs of the driver IC were wired to unused pins on the 12771 edge connector to allow easy interfacing.

The second change was to reduce resistor R300 from 260 to 56 ohms. This change provides compatibility between the modem RS-449 output level and the 12771 input circuit.

The third change was to change the transmitter clock sync flip-flop clock from 8 to 1 MHz. This change was required as the first step in synchronizing the data and clock. Otherwise the data could start on any phase of the 8 MHz clock which is not acceptable for synchronous operation. The change is implemented by cutting pin 3 of U23 at board level, bending the pin out, and wiring the pin to W1 pin D. The second step in synchronizing the data and clock was to add a monostable multivibrator triggered by the transmitter sync flip-flop. The output of the monostable is used to gate the clear line of the one-bit shift register flip-flop which generates the start bit of the data stream. Without this pulse the start bit varied in length from 0.125 to 1.000 microsecond destroying synchronization. With this pulse the start bit varied in length from 0.000 to 0.125 microseconds. The change was implemented by mounting the new IC upside down, with double sticky tape, near U64. The input was obtained from pin 8 of U64 and the output was connected to pin 1 of U64. In addition, the printed circuit board trace running from U42 pin 9 to U64 pin 1 was cut at U64 pin 1 to remove the old gating signal.

The last change required on the 12771 board was to increase the clock frequency to 1.000 MHz. The cards were all found to be running 500 to 600 Hz low. The frequency was increased by adding a 24 picofarad capacitor in series with the 8.000 MHz crystal Y1. This change was implemented by unsoldering the crystal socket pin, bending it up, and soldering the capacitor between the pin and the board.

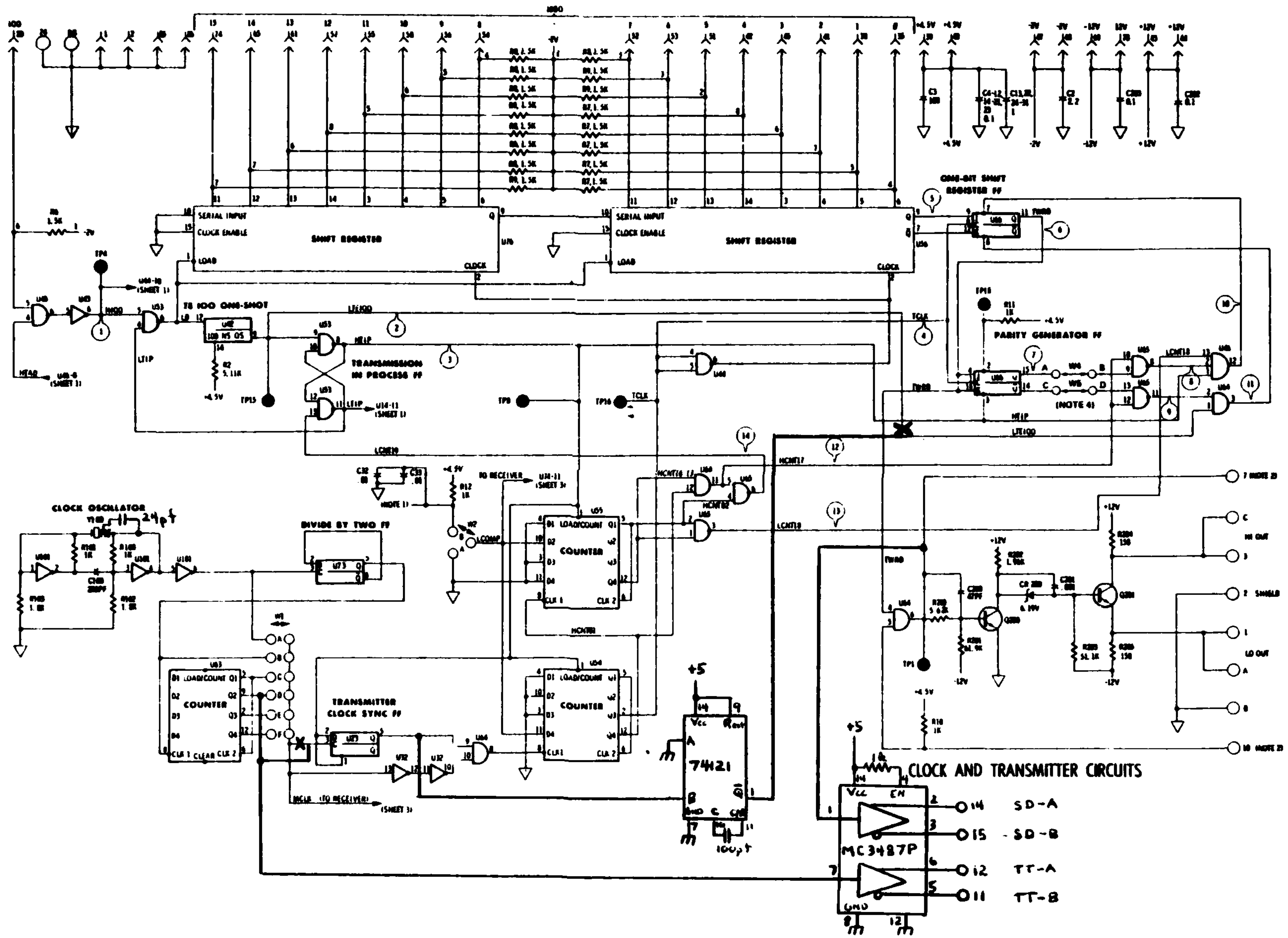

Figure B-1. Modifications to serial interface card.

```
ASMB,R
      NAM SINTF   REV B   5OCT82  CLF
*
**************************************************************************
*
*  FORTRAN CALLABLE SUBROUTINE SINTF FOR INPUT AND OUTPUT THROUGH
*  A 12771A SERIAL INTERFACE CARD.  CALLING SEQUENCE IS:
*
*          CALL SINTF(SISC,IOUT,ISTAT,IRTRN)
*
*     SISC  = SERIAL INTERFACE CARD SELECT CODE
*
*     IOUT  = WORD TO BE TRANSMITTED BY SERIAL INTERFACE
*
*     ISTAT = STATUS WORD RETURNED BY A READ
*
*     IRTRN = WORD READ BY SERIAL INTERFACE
*
*  REV B   5OCT82  CLF  ADD SERIAL INTERFACE SELECT CODE TO ARGUMENTS
*  REV A   3SEP82  CLF  ORIGINAL.
*
**************************************************************************
*
      ENT SINTF
      EXT $LIBR
      EXT $LIBX
SINTF NOP
      LDB SINTF        GET PARAMETERS
      INB
      STB ADDR        SAVE PARAMETER ADDRESS
      LDA ADDR,I      GET ADDRESS OF SELECT CODE
      LDB 0,I         GET SELECT CODE
      STB SISC        SAVE
      ISZ ADDR
      LDA ADDR,I      GET ADDRESS OF OUTPUT WORD
      LDB 0,I         GET OUTPUT WORD
      STB IOUT        SAVE
      ISZ ADDR
      LDA ADDR,I      GET ADDRESS OF STATUS WORD
      STA ADST        SAVE ADDRESS
      LDB 0,I         GET STATUS WORD
      STB ISTAT       SAVE
      ISZ ADDR
      LDA ADDR,I      GET ADDRESS OF INPUT WORD
      STA ADIW        SAVE ADDRESS
      LDB 0,I         GET INPUT WORD
      STB IWORD       SAVE
*  FORM I/O INSTRUCTIONS
      LDA SISC        MAKE LIA
      ADA LIA2
      STA LIA1
      LDA SISC        MAKE OTA
      ADA OTA2
      STA OTA1
      LDA SISC        MAKE SFS
      ADA SFS2
      STA SFS1
      LDA SISC        MAKE LIB
      ADA LIB2
      STA LIB1
      STA SISC        MAKE LIA
      ADA LIA2
      LDA LIA1
      JSB $LIBR       DISABLE INTERRUPTS AND MEMORY PROTECT
      NOP
CLC1  NOP             CLEAR CONTROL BIT & FLAG
```

```
      LDA IOUT       GET OUTPUT WORD
OTA1  NOP            OUTPUT WORD
SFS1  NOP            CHECK IF TRANSMISSION IS DONE
      JMP *-1
LIB1  NOP            READ STATUS
LIA1  NOP            READ INPUT
      STA ADIW,I     SAVE INPUT
      STB ADST,I     SAVE STATUS
      LDA SINTF,I     GET ADDRESS OF RETURN
      STA SINTF       SAVE
      JSB $LIBX      TURN ON INTERUPTS AND MEMORY PROTECT
      DEF SINTF       DEFINE RETURN ADDRESS
RTN   LDA SINTF,I     GET RETURN ADDRESS
      JMP 0,I        RETURN
ADDR  NOP            PARAMETER ADDRESS
SISC  NOP            SELECT CODE
IOUT  NOP            WORD TO BE TRANSMITTED
ISTAT NOP            STATUS WORD
ADST  NOP            STATUS WORD ADDRESS
IWORD NOP            INPUT WORD
ADIW  NOP            INPUT WORD ADDRESS
*  WORDS NEEDED TO FORM I/O INSTRUCTIONS
CLC2  CLC 0B,C
OTA2  OTA 0B
SFS2  SFS 0B
LIB2  LIB 0B,C
LIA2  LIA 0B
      END
      END$
```

```
FTN4,L
      PROGRAM SOSI(), REV B   5OCT82  CLF
C
C*****************************************************************************
C
      DIMENSION IPRM(5)
      CALL RMPAR(IPRM)
      LU=IPRM(1)
      IF(LU .EQ. 0)LU=1
      ISISC=IPRM(2)
      IOUT=IPRM(3)
      IF(IOUT .EQ. 0)IOUT=76543B
      IF(ISISC .GT. 0)GO TO 140
      WRITE(LU,100)
  100 FORMAT(" ENTER SERIAL INTERFACE SELECT CODE(OCTAL):_")
      READ(LU,120)ISISC
  120 FORMAT(O2)
  140 ISTAT=151515B
      IWORD=123456B
      CALL SINTF(ISISC,IOUT,ISTAT,IWORD)
      ISTAT=IAND(ISTAT,100007B)
      WRITE(LU,160)IOUT,ISTAT,IWORD
  160 FORMAT("IOUT = ",O6,5X,"ISTAT = ",O6,5X,"IWORD = ",O6)
      END
      END$
```

APPENDIX D - DETAILS OF MODEM TESTER

Figure D-1 is a schematic of the modem tester developed during this task. A 1.000 MHz crystal oscillator serves as the master clock for the circuit. The clock drives two 4-bit shift registers which have appropriate outputs ORed together to form an 8-bit pseudo-random number generator. In the random data mode this serves as the output bit stream which drives the modem. The clock and data are converted from TTL to RS-449 levels by a driver IC.

The data signal is applied to two variable length shift registers in series. By adjusting the length of the shift registers a delay from 1 to 128 clock cycles can be obtained. The input data and clock signals are converted from RS-449 to TTL levels. The data signal is exclusive ORed with the delayed data signal. If the two signals are the same at the instant the comparator flip-flop is clocked then no error pulse will be generated. If the two signals are different, an error pulse will be generated.

In order to determine the correct delay switch setting, a delay adjustment clock is available. When the delay adjustment mode is selected, a 3.3 kHz oscillator which is synchronized to the master clock provides a 1 microsecond pulse every 300 microseconds in place of the random data stream. By connecting a dual trace oscilloscope to pins 1 and 2 of the exclusive OR gate, the delay switches can be adjusted until the two pulses are within 1 microsecond of each other. Then the scope probes can be moved to pin 3 of the exclusive OR gate and pin 11 of the data comparator. The clock fine delay adjust can be set to give a zero level at the clock transition. The fine adjustment circuit gives approximately 0.5 microsecond of adjustment range. Once this adjustment is made, the mode can be switched back to random data and testing carried out.

An additional feature was added to allow a single error to be generated to provide verification that the circuitry is working. A push button switch is debounced and used to generate a 1 microsecond pulse synchronized with the master clock. This pulse is applied to an exclusive OR gate which causes the transmitted data bit to be inverted. However, the delayed data bit is not inverted, so a single error should occur when the received data bit and delayed data bit are compared.

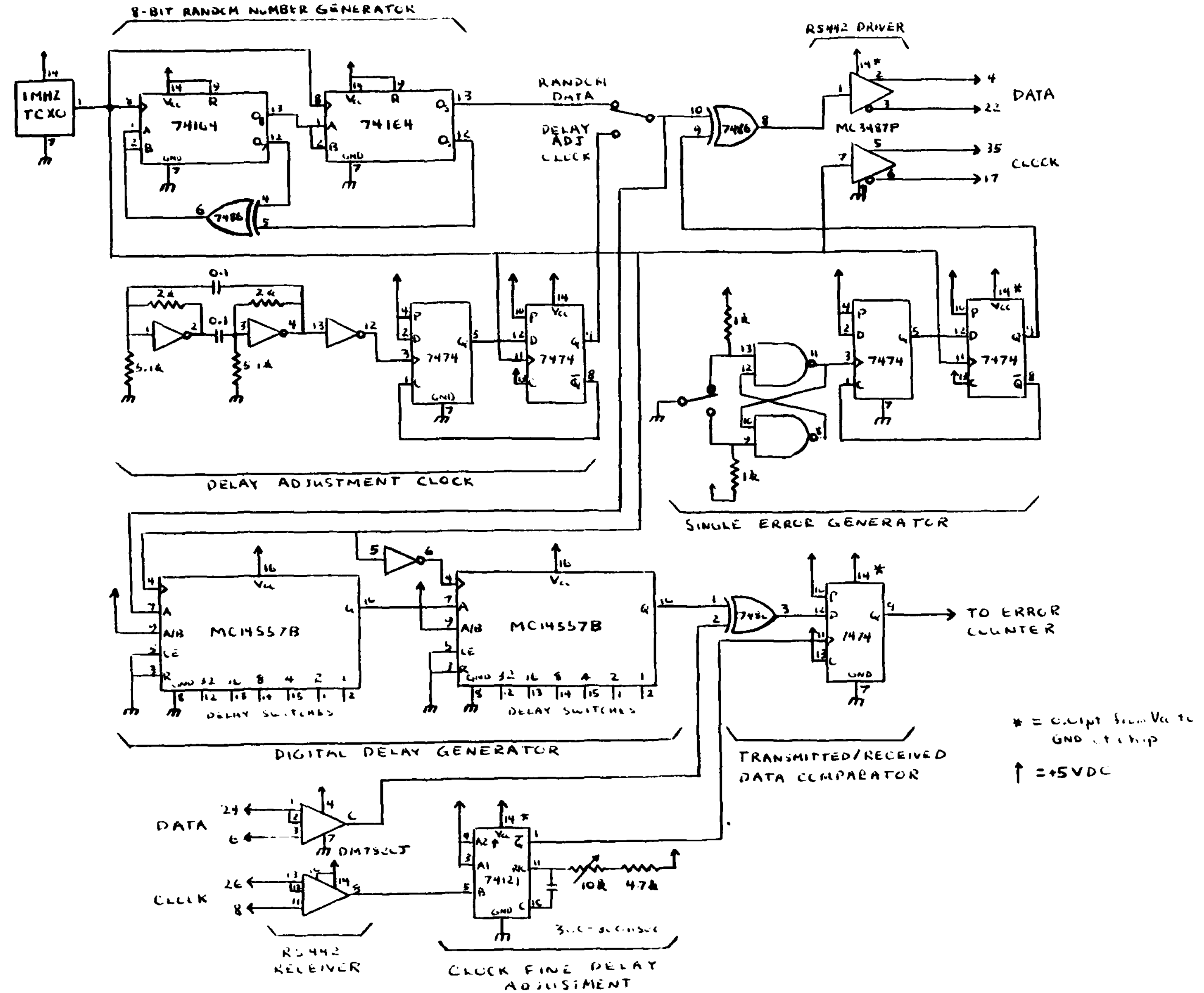

Figure D-1. Schematic of modem tester.

APPENDIX E - REFERENCES

1. Moore and Paules, RDI Task Final Report of Automated Data Acquisition and Processing Technology (ADAPT). TECOM Project No. 5-CO-APO-ADP-601. U.S. Army Aberdeen Proving Ground. Report APG-MT-4917, December 1976. (Distribution controlled by U.S. Army Test and Evaluation Command, ATTN: DRSTE-RU (now -AD-I).

2. Cunningham, Harley and Paules, RDI Task Final Report of Automated Data Acquisition and Processing Technology (ADAPT). TECOM Project No. 5-CO-APO-ADP-601. U.S. Army Aberdeen Proving Ground. Report APG-MT-5292, November 1979. (Distribution Controlled by the U.S. Army Test and Evaluation Command, ATTN: DRSTE-AD-I).

3. Study of ADAPT Communication Network, Report No. ER-12,227, AAI Corporation, under contract DAAD05-82-R-5151, February 1983.

4. M505 Broadband Modem Operation and Maintenance Manual, Fairchild Data Corporation, June 1984.

APPENDIX F - ABBREVIATIONS

AC	=	alternating current
ADAPT	=	automated data acquisition and processing technologies
AGC	=	automatic gain control
bps	=	bits per second
BTST	=	Ballistic Test Site Terminal
CATV	=	community antenna television
CCTV	=	closed circuit television
dB	=	decibel
dBmV	=	decibels relative to 1 millivolt across 75 ohms
FM	=	frequency modulation
IC	=	integrated circuit
kHz	=	kilohertz
Mbps	=	million bits per second
MHz	=	megahertz
modem	=	modulator/demodulator
TTL	=	transistor-transistor-logic
TTST	=	telemetry test site terminal

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